Intrinsic motivation of pre-service primary school teachers for learning chemistry in relation to their academic achievement

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Our experience suggests that pre-service primary school teachers have problems with learning science, especially Chemistry, and that this negative attitude towards science influences their future teaching. On that premise the purpose of the study was to determine the level of the pre-service primary school teachers' intrinsic motivation for learning science in relation to some other subjects. The focus of the research was on the intrinsic motivation for learning Chemistry and its correlation to students' academic achievements in Chemistry. The study included 140 first year pre-service primary school teachers who completed the questionnaire about their intrinsic motivation and a knowledge test about general Chemistry concepts. Their results show that students are more or less equally motivated for Chemistry as for any other subject, but that the intrinsic motivation plummets as the level of abstraction in individual subjects, such as Chemistry and Mathematics, increases. It has been similarly established that of the three levels of chemistry learning, namely, macroscopic, submicroscopic, and symbolic, students were the least motivated to study concepts at the symbolic level. The correlation between the level of motivation and the knowledge test results is not strong; nevertheless, it is statistically significant, while the correlation between motivation and the mark achieved in Chemistry is statistically not significant. The research results will assist us in our future search for more effective approaches to motivating students to study science. They can also be of assistance in encouraging students to devise educational strategies which will help them motivate their own students for science learning.

Introduction

Learning is a complex mental phenomenon in which motivation is one of the key variables. This hypothesis has been widely accepted by different schools of thought, such as Schiefele and Rheinberg (1997), linking motivation and learning and learning processes with academic results. Boekaerts (2001), one of the leading experts in the psychology of learning, sees motivation, together with cognition, as the key component and concludes that the two are inseparable and necessary in our quest to understand learners' behaviour. The cognitive component includes knowledge, skills and abilities, and motivation covers different motivational beliefs. Pintrich and Schrauben (1992) seem to share the same views in their socio-cognitive model of learning motivation. According to it, the individual's participation in the learning process is conditioned by the interaction of motivational and cognitive elements. The motivational elements include: learning self-concept, control, learning goals, interest in learning and importance assigned to knowledge. Among cognitive elements they list knowledge and learning, and general strategies of thinking. They point out, however, that both kinds of element are influenced by the nature of learning tasks (content, procedures, and sources) and by the teaching (methods, teacher's behaviour, assessment system).

Learning and intrinsic motivation

For the purposes of this paper, we define learning motivation as a construct which includes different motivational elements (interests, goals, attributes, self-image, external enticements, etc.). Some of these form a more extrinsic stimulus for learning (e.g., learning for grades, praises, avoiding punishment, social acceptance, etc.), while others are manifested more intrinsically (i.e., learning for mastering, learning for knowledge).

On the basis of findings of relevant theory and research we are especially interested in those elements which affect intrinsic motivation, as we recognise that these elements lead to construction of science knowledge on a higher level of cognitive taxonomy. According to Ryan and Deci (2000), intrinsic motivation is an individual's inherent inclination from which stems his/her tendency to learn about particular areas of life regardless of the presence of external enticements. Harter (1978) explains that intrinsic motivation is the true drive in human nature, driving us to search for the new, to face challenges, to test the boundaries of our abilities and to learn from our birth on, even when there are no external rewards to be won. Similarly, Oldfather and McLaughlin (1993, p. 3) see intrinsic motivation within the constructivist framework as a '… continuous impulse to learn', epitomised by an intense involvement with learning, curiosity and an inclination to search for meaning. According to Ryan and Deci (2000, p. 70), this construction encourages humans to '… assimilate, control, generate spontaneous interests and to research which makes it essential for the individual's social and cognitive development while on the other hand it represents the fundamental source of personal satisfaction and life energy.' Hence, learning is motivational when learning activities give the student a sense of meaning and satisfaction, which is the crucial point for progress in research and understanding of true problems in science. Namely, research has shown that extrinsic motivators are more important in the first stages of learning as they participate in the regulation of initial learning behaviour (i.e., engaging in tasks), but later they do not stimulate more than superficial strategies for learning.

In the literature on educational psychology (Eccles et al., 1998; Pintrich & Schunk, 1996; Stipek, 1998), intrinsic motivation is most frequently described in terms of three interconnected elements which the child develops by the end of primary school: (1) as a special inclination to tackle more demanding tasks which present a challenge; (2) as learning triggered off by curiosity or special interests; (3) as a development of competence and a mastering of learning tasks in which learning is seen as a value in itself. Csikszentmihalyi and Nakamura (1989) state that for the individuals who are intrinsically motivated, it is typical that: (1) they holistically engage in activities (mentally, physically); (2) they remain highly focused throughout the activity; (3) they follow clearly defined goals; (4) they remain self-critical and realistically reflect on their own actions; (5) are not afraid to fail; (6) their time flies, and (7) when learning or during learning activities they are relaxed. Research studies also show (Stipek, 1998) that such students: (1) independently start their learning; (2) they choose to do tasks or parts of tasks they find challenging; (3) they spontaneously integrate the knowledge acquired in school with their experiences gained outside school; (4) ask questions and broaden their knowledge; (5) complete additional tasks; (6) persevere to complete the tasks they have undertaken; (7) learn regardless of the presence of external enticements (marks, teacher's supervision); (8) experience and express positive emotions while learning, and (9) take pride in their work.

Intrinsically motivated learners achieve better results in knowledge tests, get higher achievements scores, have a highly positive learning self-concept. In comparison with their peers with low intrinsic motivation they show also less academic anxiety, and are less dependent on external motivational stimuli (Gottfried, 1985). Personal satisfaction experienced through learning is also linked to higher creativity (Amabile, 1985, cited in Csikszentmihalyi & Nakamura, 1989). Highly intrinsically motivated students are more successful in learning new concepts and show better understanding of the learning matter (Stipek, 1998). Rennie (1990), on the basis of the research study on science learning, also concluded that higher results in science are related to the learner's active engagement in learning tasks, to his/her positive attitude towards the subject and to a highly positive self-concept in science, which all imply the learner's intrinsic motivation to learn.

Apart from the intrinsic motivation for learning and academic results, the problem that all studies seem to encounter is a decrease in intrinsic motivation with the years spent in education. The main reason for this decrease is the underlying developmental factors and differentiation of them (Eccles et al., 1998). Ryan and Deci (2000) point out also another important reason, namely, that schooling and growing up both bring about intensified social pressures and an increasing number of roles which need to be adopted by the young learner, subsequently putting more responsibility on children regardless of the sources of their motivation.

Lepper and Henderlong (2000) present an interesting classification according to which the decrease in intrinsic motivation can be organised into four categories: (1) *external enticements, restrictions and other forms of social control* which aim to discipline learners as they progress to higher grades where the teacher-student relationship is gradually losing its intimacy, where the teaching frequently becomes quite impersonal and thus psychologically completely wrong, since the discrepancies between the student's developmental need to gain independence and school regulations which restrict personal development are growing (in the period of early adolescence); (2) *decontextualisation of learning*, which according to Bruner means inappropriate teaching strategies: abstract content unrelated to the real life in which young learners cannot see any useful application ..., more prevalent in higher grades; (3) *changes in students' objectives: learning- and goal-oriented objectives:* research studies show that even though students realise the value of learning objectives, in later years of schooling they tend to turn to goal-oriented objectives, which is probably the result of teachers' attitudes and teaching methods, and (4) *the level of cognitive challenge* which teachers should provide in relation to the students' individual features; this individual approach decreases with the years, an unsuitable level of challenge leading to a decrease in the intrinsic motivation to learn (tasks too easy, too difficult). The authors of the study believe that the intrinsic motivation for learning could in the future be maintained and encouraged by developing strategies which would block the 'demotivators' listed above.

Similar views are shared by other contemporary writers, among them Fairbrother (2000), who sees in improvements in the pedagogical approach (quality of teaching, didactic materials) an important step towards maintaining and encouraging intrinsic motivation in science learning. This is especially important; since many writers report that the decrease in intrinsic motivation with years of schooling is particularly noticeable in mathematics and science and is at its peak in the period of early adolescence (Eccles et al., 1998). The results of many studies show that the differences in intrinsic motivation to study science shown in different grades are statistically significant ($p < 0.001$) (Anderman & Young, 1994; Zusho et al., 2003). A decrease in interest for science can also be triggered by a number of incorrectly or incompletely understood scientific concepts, since students do not study science in great depth. In the past, such conclusions led researchers of science education and psychologists to reform the science curriculum, with varying success.

Learning chemical concepts

With regard to the decreasing level of motivation for science learning, it should be emphasised that science and especially chemical education ought to be organised in such a way that the pedagogical process stimulates students' intrinsic motivation for learning science. Teachers can in this way, by assuring understandable and reasonable science lessons, persuade students to achieve meaningful learning. For that reason chemistry educators and researchers have explored how three levels of chemical concepts help students develop meaningful conceptual understanding of chemical phenomena. In comparison with the triangle of three levels of chemical concepts, that were introduced by Alex Johnstone in 1982, some other authors have tried to develop different models (Chittleborough et al., 2002), which would show the connections between chemical concepts. The *ITLS (Interdependence of Three Levels of Science Concepts)* model (Figure 1) shows different levels of interdependence of chemical concepts in connection with the visualisation method used in the science classroom and mental models of chemical phenomena that this model helps students to develop.

[Insert Figure 1 about here.]

The *ITLS* model connects the concrete-sensor experimental level with the abstract-particulate submicro level and abstract-visualisation-mathematical symbolic level. Macro- and submicro levels are present in real natural phenomena; the symbolic one is only the simple human representation of that phenomena. The symbolic level helps people to communicate about the phenomena and to conduct further research if the symbols are familiar to the people that communicate to each other. An adequate mental model of the natural phenomena without misconceptions should be developed in students' long-term memory. As much as possible, a reasonable understanding of the phenomena is established when all three levels of the concept cover each other in a specific way in students' working memory. Students should be exposed to different educational strategies incorporating appropriate visualisation elements to illustrate the abstract levels of natural phenomena. Research in the last two decades shows that students have considerable difficulties in understanding the submicro and symbolic levels of chemical concepts (Chittleborough et al., 2002; Bunce & Gabel, 2002; Harrison & Treagust, 2002; Johnson, 1998; Solsona et al., 2003; Williamson & Abraham, 1995) so more thorough investigations are needed to discover which factors influences the processes in obtaining science knowledge during science lessons at all levels of education.

Purpose

The purpose of this study is to describe students' intrinsic motivation for chemistry learning and some other university subjects that are part of the primary teacher's university programme. It is also examined whether there is a correlation between students' intrinsic motivation for chemistry learning and their chemistry assessments.

Method

Participants

A total of 140 first year pre-service primary school teachers (136 females, 4 males) from the University of Ljubljana, participated in the study. On average they were 18.5 years old at the beginning of the university year. 77 % of them had at least five years of prior chemical education (two years in primary school – age 14 - 15 – and three years in secondary school – age 16 - 18), and just 23 % of the students had finished prior secondary education with less than 3 years of Chemistry. All students regularly attended the chemistry course during the 30 week period.

Research questions

The questions asked in this study are: (1) What is the level of students' intrinsic motivation for learning chemistry by comparison with some other subjects from the pre-service primary teacher's university programme?; (2) What is the level of students' intrinsic motivation for learning different levels of chemical concepts with reference to the *ITLS* model?; and (3)

What is the correlation between students' intrinsic motivation and their academic achievements based on the achievement test and their final grades in the chemistry course?.

Instruments

There are many questionnaires to measure students' attitudes or interests in science and chemical education, for example: (1) "Student Questionnaire" – TIMMS 2006 and "Student Questionnaire" – PISA 2003 and many others (e.g., "The Scientific Attitudes Inventory II - *SAI II",* Moore & Foy, 1997; "Test of Science-Related Attitude" – *TOSRA",* Fraser, 1978; "Students' motivation towards science learning – *SMTSL",* Tuan, et. al., 2005; "The Chemistry Attitudes and Experiences Questionnaire" – *CAEQ",* Coll, et al., 2002; etc.). All these instruments show the rather general structure of students' attitudes towards science, but they lack the dimension with reference to the *ITLS* model and separately for different subjects. These questionnaires do not show enough specific characteristics regarding the research questions asked in this study and would need extensive revision for adapting the instrument to tertiary level. For those reasons the new instrument for measuring intrinsic motivation was developed by the authors following the general lines of the "Children's Academic Intrinsic Motivation Inventory" (*CAIMI*) developed by Gottfried (1986), which fall into the category of more general psychological instruments, and the *SMTSL* and *CAEQ* questionnaires that comprise items more directed towards science and chemistry learning. After analysing the questionnaires, the adjustments of some relevant items were made and a new "Intrinsic Motivation for Learning Science" (*IMLS*) questionnaire was developed.

The 125-item *IMLS* questionnaire assesses intrinsic motivation for learning biology (*IMLS biology*), physics (*IMLS physics*) and chemistry (*IMLS chemistry*) as well as general intrinsic motivation for studying (*IMLS general learning*) and motivations for learning mathematics (*IMLS mathematics*) and foreign language (*IMLS foreign language*). In the part of *IMLS* for chemistry special attention is directed to the assessment of students' intrinsic motivation for learning chemical concepts on the three levels according to the *ITLS* model (i.e. *IMLS macro*-, *IMLS submicro*- and *IMLS symbolic*). The response to each item is on a five-point Likert-type scale anchored at 1 = strongly disagree, 2= disagree, 3 = sometimes disagree, sometimes agree, 4 = agree, and 5 = strongly agree. The internal consistency (Cronbach α) of *IMLS* was .78. The validity of the proposed multidimensional model of intrinsic motivation was also confirmed by correlation calculations (Table 1). The correlation matrix shows that the items measuring intrinsic motivation for learning different levels of chemical concepts and for learning chemistry in general are related in content and meaning. Three sample items of each component of intrinsic motivation from the *IMLS* questionnaire are included in Appendix 1.

[Insert Table 1 about here.]

To determine the basic understanding of chemical concepts the "Test of Basic Chemical Knowledge" (*TBCK*) was applied.

TBCK comprises 14 chemistry problems which require understanding of chemical concepts at all three levels with respect to the *ITLS* model. The *TBCK* was developed out of problems published by Mulford and Robinson in *Journal of Chemical Education* (2002). Six items were modified and were used as open-ended questions, and one was used unchanged. Two problems were used following the work of Miller (R. Miller, personal communication, September, 2003), and four of them were developed by the authors. The construct validity of the instrument was confirmed by three independent experts in science and chemical education. The *TBCK* showed satisfactory internal consistency (Cronbach α = .72). Six sample items from the *TBCK* are included in Appendix 2.

Research design

Students were exposed to the 30-week chemistry course at the Faculty of Education, University of Ljubljana, Slovenia, prior to participating in the study. The main areas of the chemistry course are: particles of matter (atoms, molecules, ions), chemical reaction, energy and chemical reactions, chemistry of fuels and energy sources, the structure of atoms and molecules, status of matter; the control of chemical reactions (chemical kinetics, chemical equilibria), acids and bases, electron transfer reactions, the chemistry of elements (the main group elements, transition elements), the chemistry of carbon (hydrocarbons, the hydrocarbon derivatives, carbohydrates, fats, proteins, polymers, nutrition) and environmental chemistry (air, water and soil pollution). The work in the course is organized in the form of: 30 lectures (45 min period, 30 weeks), lab work (90 min period, 10 weeks), seminars (90 min period, 3 weeks), field work (2 days), and individual tutorials. 70 % of the final grade is contributed by three quizzes and the final oral exam, and 30 % of the final grade represents achievements in the lab and field work and seminar. Some topics of the course are run in such a way that students are as much as possible stimulated to connect the three levels of chemical concepts regarding the *ITLS* model.

Both instruments were administrated in groups at the end of the chemistry course following standard procedures. *IMLS* data were analysed using descriptive statistics and the paired-samples t-test. *TBCK* data were first qualitatively analysed and then test final scores were calculated and used in this study. Pearsons' correlation coefficient was used to determine the correlation between students' intrinsic motivation and their academic achievements.

Results

The results are presented in three sections. The first section shows characteristics of students' intrinsic motivation for learning chemistry in relation to other subjects at university level, the second one concentrates on the intrinsic motivation for learning chemistry with reference to the *ITLS* model, and the last one presents the correlations between intrinsic motivation and students' academic achievements (i.e. achievement test, chemistry course grade).

Students' intrinsic motivation for learning chemistry and other university subjects

Pre-service teachers in their first year of university studies are the most highly intrinsically motivated for learning biology; they show relatively high intrinsic motivation for learning indeed, but they are less intrinsically motivated for learning mathematics, foreign language, physics and chemistry (Figure 2).

[Insert Figure 2 about here.]

The differences between intrinsic motivation for learning different subjects are statistically significant (Table 2). The most notable is the difference between general motivation for learning and motivation for learning chemistry ($t = 10.15$; $df = 139$; $p = 0.000$), while it is also important to point out that there are statistically insignificant differences between the general motivation for learning and that for learning biology ($t = - 1.41$; $df = 139$; $p = 0.161$), and the motivation for learning chemistry and that for learning mathematics ($t = - 1.42$; $df = 139$; $p = 0.156$). By comparing the intrinsic motivation for learning individual science subjects we found that the most notable statistically significant difference exists between the motivations for learning chemistry and biology ($t = -9.12$; $df = 139$; $p = 0.000$).

[Insert Table 2 about here.]

Intrinsic motivation for learning chemistry with respect to the ITLS model

Among the three measured levels of chemical concepts regarding the *ITLS* model, the students' intrinsic motivation for learning was highest at the concrete – macro level of understanding (significantly above the average 35 points), while the other two levels, more abstract in their content (submicro– and symbolic levels), were found to be represented to a much lesser degree (Figure 3).

[Insert Figure 3 about here.]

The differences in intrinsic motivation for learning chemistry concepts at all three levels of the *ITLS* model are statistically significant (Table 3). The highest level of difference is in the intrinsic motivation for learning chemistry concepts at the macroscopic and symbol levels ($t = 15.93$; $df = 139$; $p = 0.000$) and the macroscopic and submicroscopic levels ($t = 15.01$; $df = 139$; $p = 0.000$). The lowest level of difference, although still statistically significant, was in the motivation for learning chemistry concepts at submicroscopic and symbol level ($t = 4.57$; $df = 139$; $p = 0.000$).

[Insert Table 3 about here.]

The relation between intrinsic motivation and academic achievements based on test scores and the final grade of chemistry course

The results show that the intrinsic motivation for learning chemistry, both in general and at the submicroscopic level, is statistically significantly correlated with knowledge but not with the students' exam results (Table 4 and 5). The correlation between the knowledge test (*TBCK*) and the exam results is low and statistically significant ($r = 0.27$; $p = 0.002$). In the knowledge test, students scored on average 15.02 points (55.6 %) out of 27 points (SD = 4.19), whereas in the chemistry exam, students scored on average 7.2 (SD = 0.83) out of 10 points.

Table 4 shows that the students' test results are just positively, yet still statistically significantly, correlated with the intrinsic motivation for learning chemistry ($r = 0.30$; $p = 0.000$), or rather with the intrinsic motivation for learning chemistry concepts at the submicro level ($r = 0.20$; $p = 0.018$).

[Insert Table 4 about here.]

There were no statistically significant correlations between the final exam result in chemistry and intrinsic motivation for learning chemistry, be it in general or for learning at individual levels, as shown in the *ITLS* model (Table 5).

[Insert Table 5 about here.]

Discussion

Students' intrinsic motivation for learning chemistry and some other university subjects

Researches have shown (e.g., Watters & Ginns, 2000) that class teachers are well motivated for teaching various subjects, but are least motivated towards teaching science.

The results indicate that future class teachers in their first year of the graduate programme are intrinsically motivated towards learning. We found out that our students maintain the highest level of intrinsic motivation for learning biology and the lowest for learning chemistry. From the gender point of view (97 % females), the result is not unexpected and confirms what other authors have found (Adamson et al., 1998; Meece & Jones, 1996); namely the research results clearly show that male students are more positively inclined than females towards science. Among science subjects, female students prefer biology, whereas males tend to be more interested in maths, physics and chemistry. Based on various research studies, Brickhouse, Lowery and Schultz (1999) have concluded that female students are 'alienated from science' (p. 441) because it incorporates too many attributes (e.g. impersonal, objective, competitive) which do not agree with the stereotype female role still prevalent in our society. Progressively, with years of schooling and their personal development, girls increasingly devote less time to science learning and on the basis of their poor results in this area they also develop a poor self-concept (Brickhouse et al., 1999).

The results seem to indicate that students on the one hand equate the intrinsic motivation for learning biology with the intrinsic motivation for learning in general, and on the other, they equate the intrinsic motivation for learning mathematics with the intrinsic motivation for learning chemistry. To an extent, this is understandable, since intrinsic motivation is mainly related to the choice of study programme and future occupation. Such results, however, can also lead to the conclusion that future teachers in general show a higher level of intrinsic motivation for subjects and studies of a rather concrete nature. In future, it could be important to research how much this result is related to the students' prevalent learning styles. For example, it is possible that the accommodative style, otherwise typical of teachers, is also present in students' inclination towards concrete experiences and concrete situations. Students with high levels of intrinsic motivation for learning abstract or more specific topics most probably do not choose to become class teachers but rather decide to undertake mathematical, scientific, technical and linguistic studies (Kolb, 1984). Another research study on the gender differences in studying science subjects which deserves a mention is that of Bunce and Gabel (2002). The authors argue that the differences are the result of different mental models which enable meaningful learning. Their conclusion is that female students, who generally acquire less knowledge in science than their male peers, are more successful in solving chemistry problems when they develop strategies to construct such models through picture-based teaching. In other cases, female students' results in chemistry tests of non-macroscopic nature are lower, which affects the shaping of their self-concept in science and consequently leads to a decrease in their intrinsic motivation for learning in science.

Slovenian authors (Devetak & Glažar, 2001) have also pointed to inappropriate teaching methods as the potential reason for the lower motivation for learning science and chemistry among future teachers. This aspect is especially important because it addresses the problem of studying unpopular science topics in the undergraduate programme of class teachers, and also questions the quality of subsequent science teaching in primary schools in Slovenia.

Intrinsic motivation for learning chemistry with reference to the ITLS model

The level of students' intrinsic motivation to study chemistry according to the *ITLS* model (Figure 1) also decreases as chemistry topics become more demanding. Johnstone (1991) comes to a similar conclusion in his presentation of results from studies of the early grades of schooling where differences in intrinsic motivation at individual levels of chemistry concepts are already apparent. These results seem to indicate that students are relatively highly motivated to study chemistry at the macroscopic level, which includes observations of chemical changes, and considerably less motivated to study chemistry at the submicroscopic and symbolic levels. Their strong motivation for study at the macroscopic level again confirms the above hypothesis that future class teachers prefer concrete topic and teaching situations. The submicroscopic and symbolic levels, as opposed to the macroscopic level, require students to learn about particles of substances (atoms, ions, molecules) and how to code chemistry symbols, formulae and equations of reactions, which is a considerably more demanding task in terms of knowledge, abstract concepts and understanding. For these reasons we can assume that students in the course of their studies do not acquire sufficiently high quality knowledge in chemistry to be able to transfer the chemistry phenomena and their submicroscopic and symbolic representations (Lee, 1999) – which probably contributes to their poor understanding – to the application of superficial learning strategies, subsequently leading to a decrease in their intrinsic motivation to study chemistry, especially at the symbolic level. If all three levels of chemistry concepts are not integrated in the students's mental model then learning chemistry loses its meaning, it becomes alienating and remains at the level of memorising without understanding. Such learning can only be encouraged by external motivational stimuli which are either positive (e.g. the desire to achieve good marks, to finish the year) or negative (e.g. fear of failure, fear of losing one's grant).

The relations between intrinsic motivation and academic achievement

These results show a weak but nevertheless a statistically significant correlation between chemistry knowledge and students' general intrinsic motivation for learning chemistry. Other studies present similar results (Devetak, 2005; Gottfried, 1985; Juriševič, 2005). A statistically significant but still low positive correlation has emerged between knowledge in chemistry and the students' intrinsic motivation for learning chemistry at the submicroscopic level, which is a result aligned with the theory. Those students who claim they are intrinsically motivated towards learning chemistry are in fact motivated towards learning chemistry concepts at the submicroscopic level (Table 1), for these topics are in fact the key in the *ITLS* model to understanding chemistry or rather to the acquisition of meaningful knowledge in chemistry and science literacy. Intrinsically motivated students in their learning apply in-depth learning strategies; hence, their knowledge is of a higher quality, which is reflected in their knowledge test results (Schiefele & Rheiberg, 1997; Ward & Bodner, 1993). The question of why our study did not confirm the relationship between exam results and intrinsic motivation still remains open, and so does the established positive relation between the *TBCK* test results and the exam results. It is possible that, because the exam situation is so clearly goal-oriented (pass the exam or fail it), the result is more under the influence of external rather than internal stimuli: these issues remain to be researched in the future, together with some other students' personal traits. With regard to external motivation it would also be important to study the relations between intrinsic motivation and the forms which assessment of knowledge in chemistry takes: our research only looked at the written *TBCK* test, while the exam had both a written and an oral component.

Conclusions and implications for teaching

The main conclusion of this study confirms that students are intrinsically motivated towards learning in general, but it cannot simply be generalised that students are not intrinsically motivated towards learning chemistry. It seems better to argue that students show low levels of intrinsic motivation for explaining experimental observations at submicroscopic level and for communicating the conclusions derived from experimental data by means of symbolic chemical language. Students' intrinsic motivation for observing chemical phenomena is almost as high as their intrinsic motivation for learning biology, but on the other hand students demonstrate equal levels of interest in chemistry and mathematics. It can be concluded from these results that pre-service primary school teachers show interest in more concrete content, while abstract content gives rise to anxiety, because students are probably not sufficiently self-confident in their previous science knowledge. We found that their understanding of basic chemical concepts is also more superficial.

On the other hand, it is interesting to focus on students' motivation for learning science; Brickhouse et al. (1999; p. 456) noted that 'neither the students, teachers, nor parents talk about understanding when they are talking about success in school science'. In fact the understanding of science phenomena plays a marginal role, as in schools – in Slovenia for example – success in science is measured mostly in terms of grades and points. This raises the question about the vertical nature of compulsory education. It is not obvious in our study that students are intrinsically motivated to 'pass successfully' – it is possible that the other motivational constructs (extrinsically based), which participate at all levels of students' education (primary, secondary and university levels), are the ones which we should explore in the future, as we believe that they might strongly influence the formation of preserving the teacher's pedagogical approach. We allow ourselves to speculate that students may have negative previous experience in chemical education especially at secondary level, because the secondary school curriculum – and particularly chemistry lessons – includes the writing of numerous calculations and chemical equations which the students (may) regard as nonsense. This negative experience in the chemistry classroom is then reflected at university level. For that reason, lessons ought to be designed to enable students to be logical, reasonable and connected with real world experience in order to make chemistry more interesting. At primary and secondary level education the courses should be developed in such a way that students would observe experiments and explain the observations at submicroscopic level. After introducing the submicro level of chemical concepts students should develop the skills to symbolically communicate experimental observation. It can be confirmed that students in secondary school are not exposed to educational strategies that would lead to sufficient understanding of science concepts with regard to *ITLS* model. The university course for science education (chemical topics) for pre-service teacher education should be emphasised with respect to the *ITLS* model. It is also important to point out that a very short tertiary level course in science education is not enough to sufficiently re-motivate students for chemistry learning; that is why students enter university education quite demotivated for science learning because of the ineffective secondary level education regarding positive motivation towards chemistry learning.

Furthermore, more precise research must be conducted into the influences affecting the development of motivation for studying and teaching science, especially chemistry. Once the sources and reasons for the strong extrinsically-based motivation towards science learning are revealed, special strategies to stimulate teachers' and students' intrinsic motivation should be developed and applied in the school environment, in order to stimulate higher cognitive reasoning. It can be concluded that chemical education at all levels would become more suitable, once it becomes more meaningful for students. On the other hand, more emphasis should also be accorded to research into the strong influence exerted by teachers through their pedagogical methods, and especially to the strong influence exerted by the family environment and by gender stereotypes on the formation of the pre-service female teacher's pedagogical approach.

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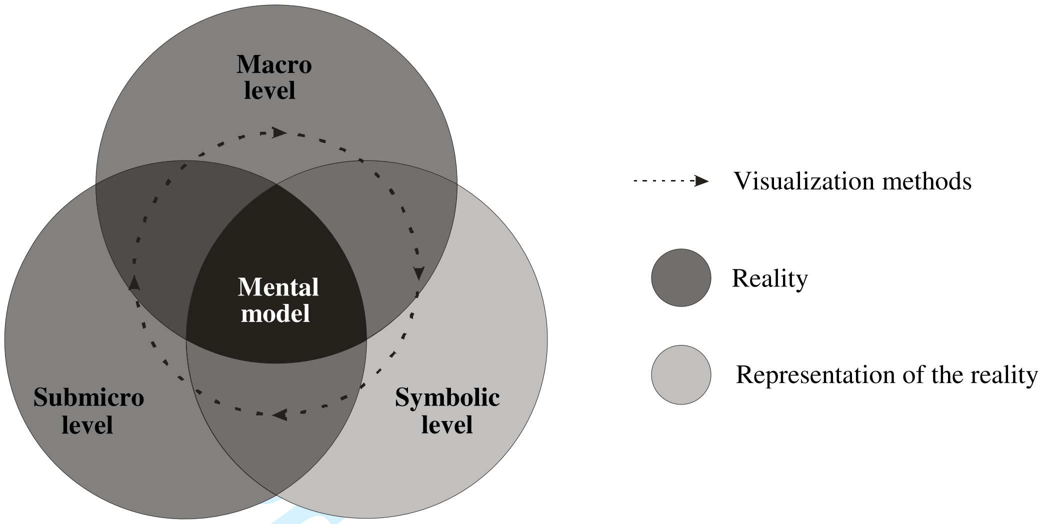


Figure 1. Model representing Interdependence of Three Levels of Science Concepts – ITLS model (Devetak, 2005).

Table 1. Correlations between intrinsic motivation for learning chemistry in general and for learning chemistry on the three levels of chemical concepts according to the ITLS model.

Type of motivation	*IMLS chemistry*	*IMLS macro*	*IMLS submicro*	*IMLS symbolic*
IMLS chemistry	1.00			
IMLS macro	0.51**	1.00		
IMLS submicro	0.66**	0.35**	1.00	
IMLS symbolic	0.65**	0.21*	0.60**	1.00

* $p \leq 0.05$; ** $p \leq 0.01$

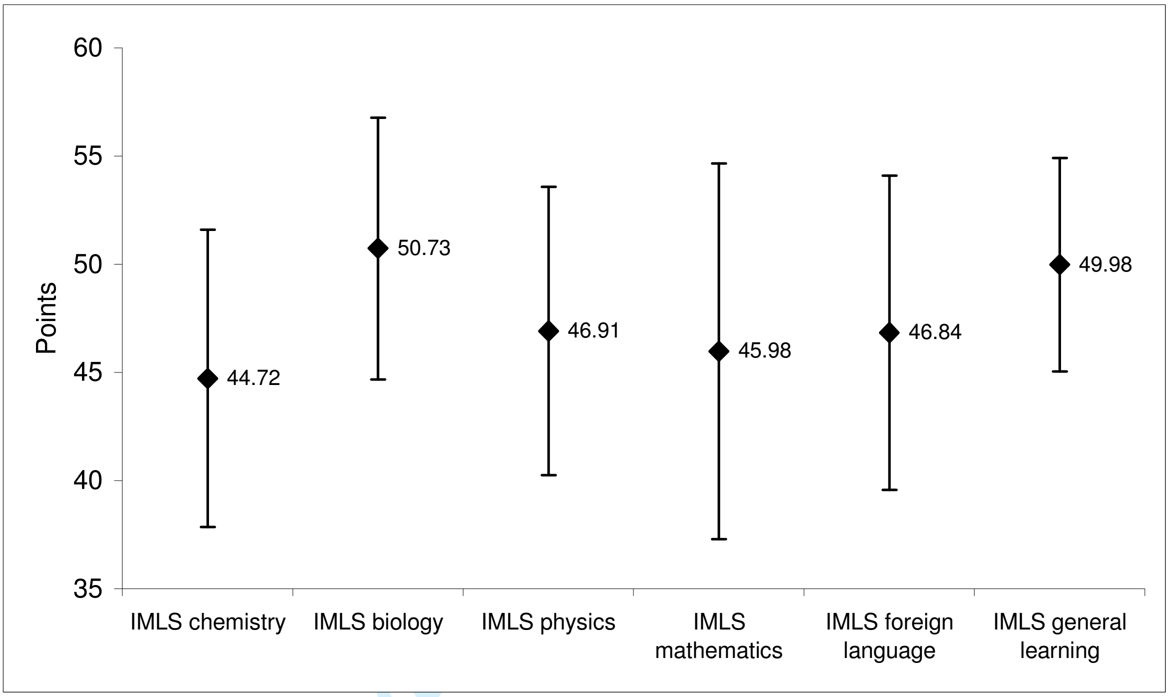


Figure 2. Student's intrinsic motivation for learning university subjects (mean values and standard deviations).

Table 2. Differences in means between different types of intrinsic motivation.

Type of motivation compared	*t*	*df*	*p*
IMLS general – IMLS chemistry	10.15	139	0.000
IMLS general – IMLS biology	-1.41	139	0.161
IMLS general – IMLS physics	5.67	139	0.000
IMLS general – IMLS mathematics	5.42	139	0.000
IMLS chemistry – IMLS biology	-9.12	139	0.000
IMLS chemistry – IMLS physics	-3.82	139	0.000
IMLS chemistry – IMLS mathematics	-1.42	139	0.156

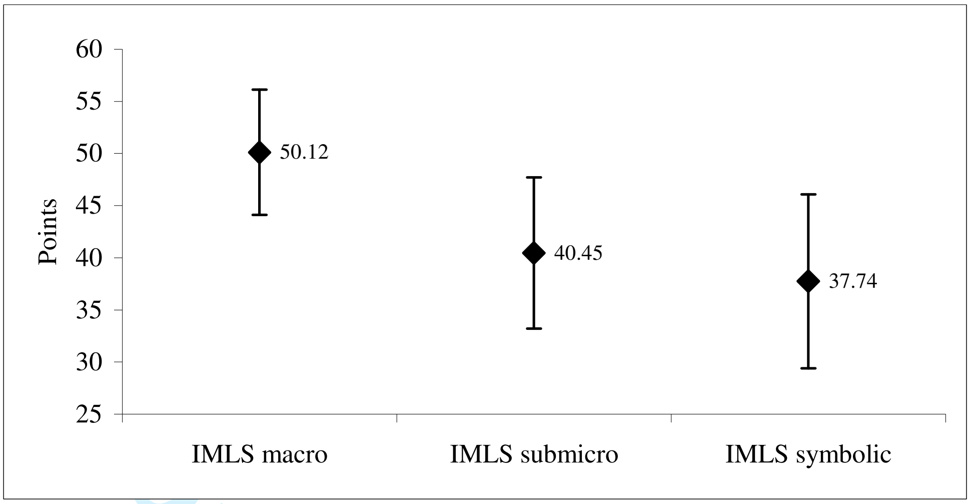


Figure 3. **Student's intrinsic motivation for learning chemistry at different levels of chemical concepts (mean values and standard deviations).**

Table 3. **Differences in means for intrinsic motivation for learning chemistry at different levels of the *ITLS* model.**

Type of motivation compared	*t*	*df*	*p*
IMLS macro – IMLS submicro	15.01	139	0.000
IMLS macro – IMLS symbolic	15.93	139	0.000
IMLS submicro – IMLS symbolic	4.57	139	0.000

Table 4. Correlation between TBCK score and intrinsic motivation.

	IMLS chemistry	*IMLS macro*	*IMLS submicro*	*IMLS symbolic*
TBCK	0.293*	0.075	0.200*	0.117

*p ≤ 0.05

Table 5. Correlation between final chemistry course grade and students' intrinsic motivation for learning chemistry.

	IMLS chemistry	*IMLS macro*	*IMLS submicro*	*IMLS symbolic*
Final grade	0.123	0.025	0.022	0.100

Appendix 1: Sample items from the questionnaire Intrinsic Motivation for Learning Science (*IMLS*)

1. Emotional component of interest:

I enjoy learning.

I am often board during:

…chemistry course.

… biology course.

…physics course.

… foreign language course.

… mathematics course.

I enjoy chemistry course when:

…we observe chemical changes in experiments.

…we learn about particles (atoms, ions, molecules).

…we learn and write chemical symbols, formulae and equations.

2. Cognitive component of interest:

I often look for additional information about school science topics in books, magazines, internet, CDs …

Media attract my attention when reporting:

…chemistry topics.

…biology topics.

…physics topics.

…foreign language topics.

…mathematics topics.

I often think about:

…observation of chemical changes in experiments*, also out of school.*

… particles (atoms, ions, molecules), *also out of school.*

…learning and writing chemical symbols, formulae and equations, *also out of school.*

3. Challenge component of internal motivation:

I persevere with learning.

New problems in:

… chemistry, *challenge me.*

…biology, *challenge me.*

…physics, *challenge me.*

…foreign language, *challenge me.*

…mathematics*, challenge me.*

If I do not understand something, connected with:

…observation of chemical changes in experiments, *I give up.*

…learning about particles (atoms, ions, molecules), *I give up.*

…learning and writing chemical symbols, formulae and equations, *I give up*.

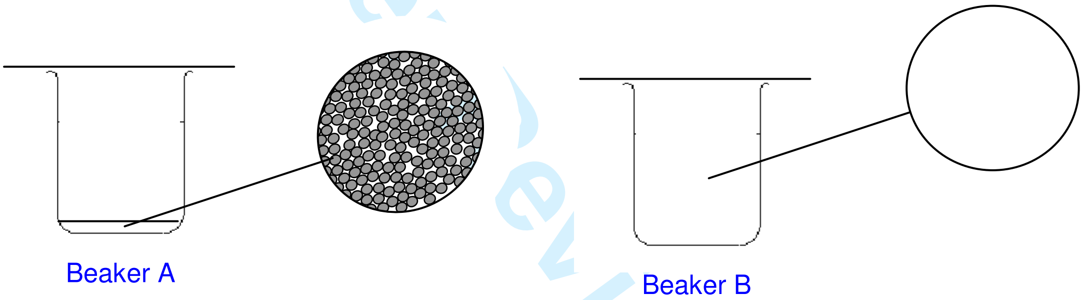
Appendix 2: Sample items from Test of Basic Chemical Knowledge (*TBCK*)

1. We add 20 g of sugar into 200 mL of water.

   1.1. What is the weight of the resulting solution? ___________

   1.2. Give your reasons for the answer. ____

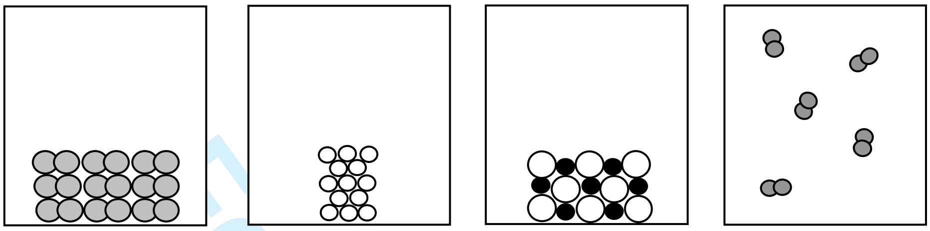
2. In the closed beaker A is liquid water. The circle on the left represents much magnified view of a very small part of the water. Water is being heated, to the point where all evaporates (Beaker B). Into the circle on the right (Beaker B) draw the representation of the magnified view after all the water evaporates.



3. We put 2 g river sand and 290 g concentrated hydrochloric acid into the 350 g plastic bottle. The plastic bottle was corked immediately. The gas was formed in the bottle. The bottle was weighted after the chemical reaction finished. How much the balance showed? _________

   3.1. Give your reasons for the answer. ____

4. Pictures (from 1 to 4) represents particles in different substances from A to E at T = 25 °C and P = 101,3 kPa. Under each picture write a letter beside the formula of the substance, which structure is in the picture.



Picture 1 ______ Picture 2 ______ Picture 3 ______ Picture 4 ______

Choose between substances represented by these formulae:

A Cl_2 B I_2 C Ca D NaCl E O_3

5. Following is a list of properties of a sample of oxygen gas:

A Colourless, heavier than air, it makes combustion possible.

B Melting point of -218,75 °C.

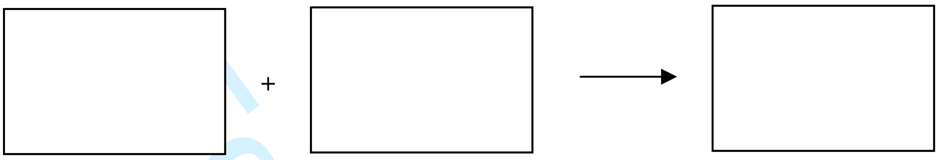
C 20,95 % in the air.

D It does not conduct electricity.

E Combines with magnesium to form magnesium oxide.

Which of these properties would be the same for one single molecule of oxygen obtained from the sample? ______________

6. Nitrogen reacts with hydrogen, and ammonium is formed. The chemical reaction could be presented as: **nitrogen + hydrogen → ammonium**. The picture under represents this chemical reaction. Atom of nitrogen can be represented as ●, and the atom of hydrogen as ○ .



Which of the chemical equations represents the chemical reaction shown in the picture?

A $N + 3\ H \rightarrow NH_3$

B $NH_3 \rightarrow N_2 + H_4$

C $N_2 + 3\ H_2 \rightarrow 2\ NH_3$

D $N + 2\ H_2 \rightarrow NH_4$

E $N_2 + 2\ H_2 \rightarrow 2\ NH_2$

Note: Blank lines are longer in the original test. They are cut short to save space.